

G7. Ultrasounds

I. INTRODUCTION

This experiment reviews the basic principles of *geometric acoustics* and *wave acoustics*. using ultrasounds, whose frequencies (~ 40 kHz) are over the human hearing limit.

Ultrasounds here will be produced using a piezoelectric resonator. This resonator is made of a dielectric ceramic plate placed between the two electrodes of a capacitor. If an electric voltage is applied to the capacitor, mechanical flexion oscillations are induced (piezoelectric effect). This system works at the eigenfrequency of the ceramic plate. On the front side of this small plate is a cone, that can convert the vibrations to ultrasounds in the atmosphere.

The electric-mechanical conversion of these transducers is completely reversible, which allow them to be used as both emitters and receivers.

In fact, and ultrasound wave can induce vibrations of the ceramic plate. Through the piezoelectric effect, these vibrations generate an electric voltage that can easily be amplified.

II. AVAILABLE EQUIPMENT

- A *mechanical bench*, with transducers that have resonant frequencies of 40 and 48.6 kHz , and can be used to measure the bandwidth of resonant transducers, the speed of sound waves in continuous or pulsed mode, and observe beat frequencies of two ultrasound waves
- Transducers placed in cylindrical containers, with black and yellow connectors (ground and signal respectively)
- An *emission generator* that can be used to generate continuous or pulsed waves.
- A *reception amplifier* that can be used as a basic amplifier for viewing the incoming wave, or as a *rectifier amp* to perform measurements on the incoming wave. It is sometimes necessary to charge the output of the amplifier with a resistor of approx. $1\text{ k}\Omega$, on the input of the oscilloscope to get rid of the 50 Hz electric perturbations.
- A *function generator* as well as *frequency meters*.
- An *oscilloscope* and an *X-Y plotter* that can be used to visualize the phenomena.

Before each setup on the bench, in order to ensure optimal working conditions, make sure the emitter and receiver transducers are well aligned. Once optimally aligned, the transducers must be placed on their resonant frequency. Only then should you adjust the gain of the amps and the scale of the oscilloscopes.

III. EXPERIMENTS

1) Frequency response of resonant transducers

The transducers have a frequency response with two very well defined peaks. The response can be measured using the setup of figure 1.

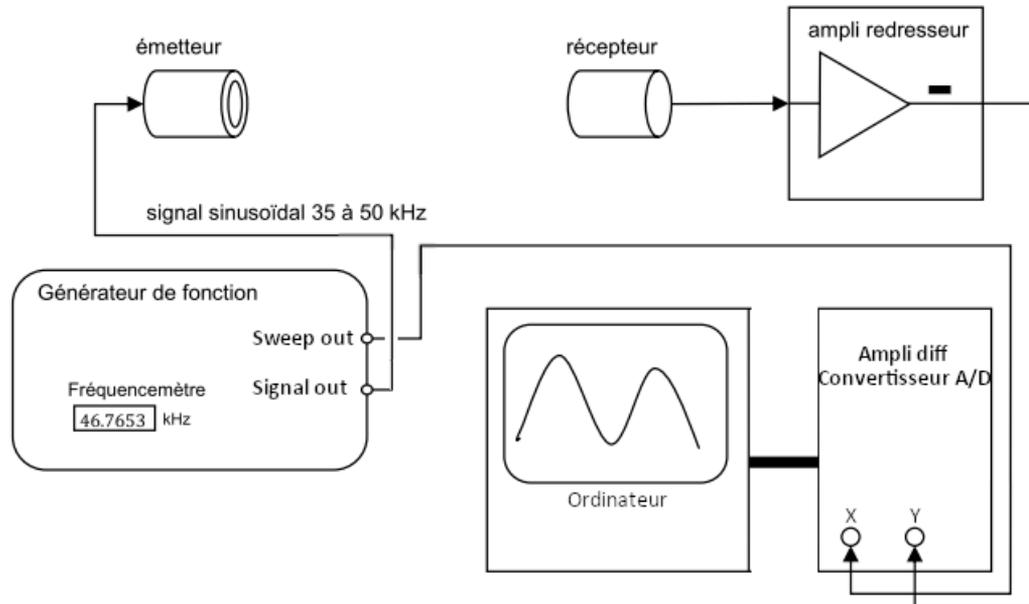


Fig 1 : experimental setup.

Suggested Experiment: Vary the frequency of the emitter between 35 and 50 kHz using the frequency sweep option of the function generator. Using the PlotterXY program measure the amplitude of the response (*bandwidth* of the emitter-receiver total) as a function of frequency (output “sweep out” of the generator gives a voltage proportional to the frequency). Plot the response versus the frequency, and discuss.

2) Measuring the speed of sound with continuous waves

The speed of sound c is connected to the wavelength λ and the frequency f according to:

$$c = \lambda f$$

In the setup shown in figure 2, we synchronize the horizontal sweep of an oscilloscope with the continuous wave sent by the emitter, and watch the incoming wave from the receiver. If we modify the distance d separating the emitter from the receiver, we will see wave oscillations pass on the oscilloscope. For each movement of one period, the distance d is moved by a distance λ .

Suggested experiment: Vary the distance d separating the emitter from the receiver, in order to move the signal on the oscilloscope by an integer number of wavelengths (i.e. take measurements for n from 1 to 20), and calculate the speed of sound from the obtained results. How precise are the results?

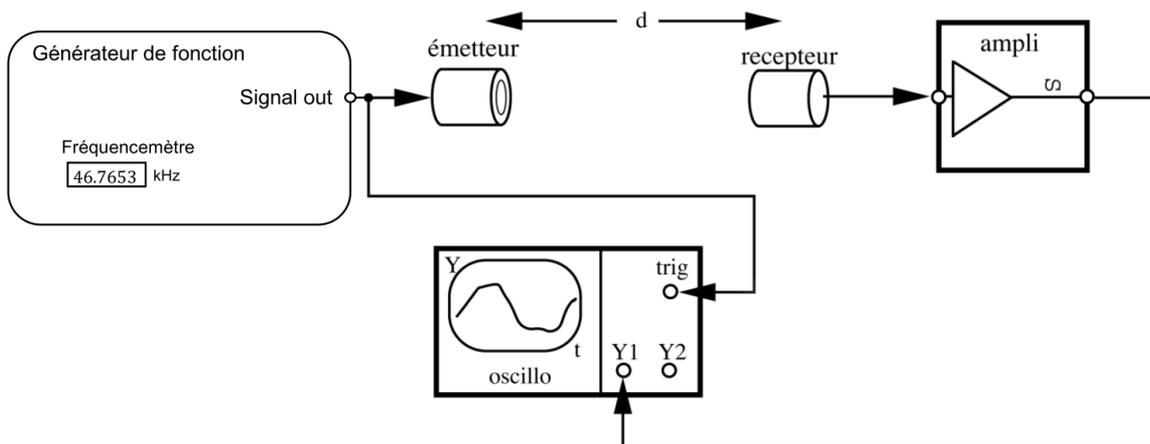


Fig 2 : Experimental setup for continuous waves

3) Measuring the speed of sound with pulsed waves

Using the setup shown in figure 3, we can build a system that works like *sonars* or *radars*. A wave pulse is sent regularly, several hundred times each second by the emitter. The pulse is reflected by an obstacle (here, a metal plate) and bounces back towards the receiver. If we compare the received pulse to the emitted pulse, we can see the travel time τ of the received signal after having travelled a distance $2d$.

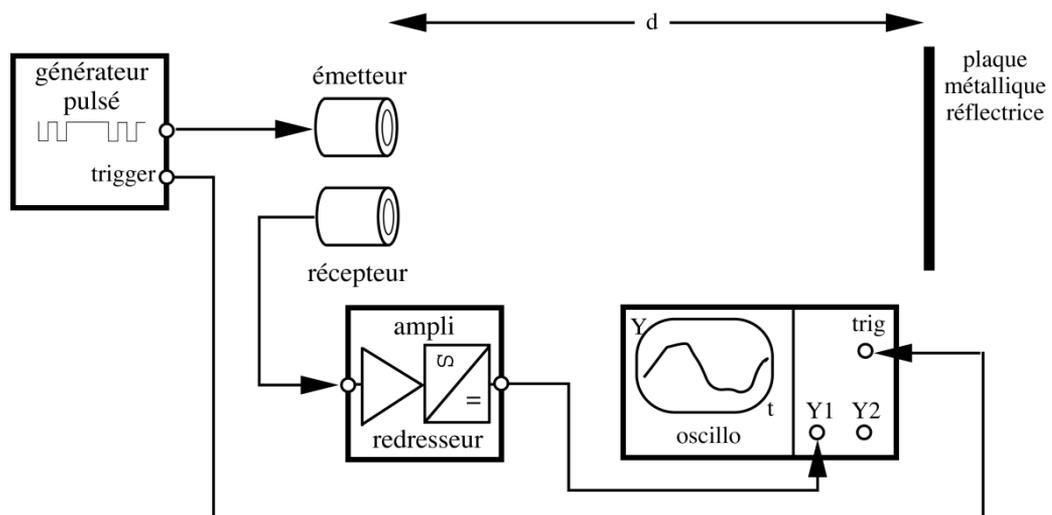


Fig 3 : Experimental setup for pulsed waves.

Suggested experiment: Vary the distance d separating the transducers from the plate, and measure the signal's travel time variation Δt . Use this information to determine the speed of sound. How precise is this method? Compare it to a method using continuous waves.

4) Temporal interference between two waves (beat phenomenon)

When two wave of slightly different frequencies f_1 and f_2 superimpose, a temporal interference phenomenon appears. This effect is called *beat*. The addition of two waves can be written:

$$A(t) = A_1 \sin(2\pi f_1 t + \phi_1) + A_2 \sin(2\pi f_2 t + \phi_2)$$

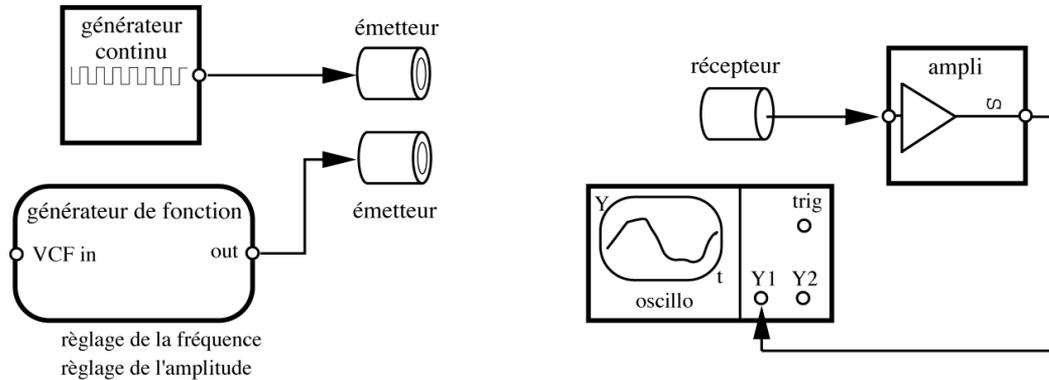


Fig 3 : Experimental setup for interference.

In the simplest case, the amplitudes A_1 and A_2 and phases ϕ_1 and ϕ_2 are equal, so we can write the superposition as a product of a wave of average frequency $(f_1 + f_2)/2$ modulated in amplitude by a frequency $|f_1 - f_2|/2$

$$A(t) = 2A \cos\left(2\pi \frac{|f_1 - f_2|}{2} t\right) \sin\left(2\pi \frac{f_1 + f_2}{2} t\right)$$

Suggested Experiment : Do the setup shown in figure 4, and observe the beat phenomenon, by varying the frequencies f_1 and f_2 , as well as the amplitudes A_1 and A_2 . Compare the experimentally obtained results (numerical values) to the theoretical ones.

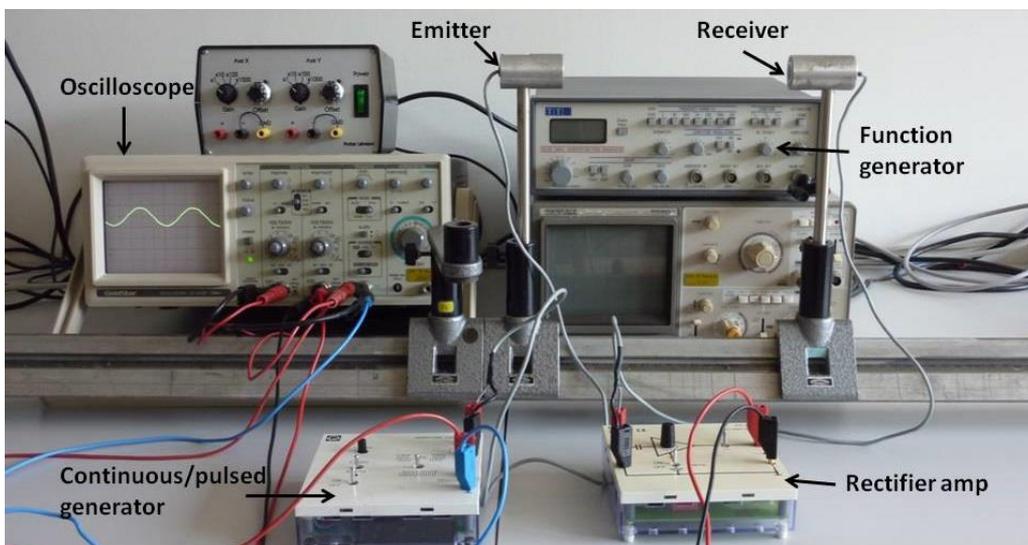


Fig. 5: Photo of the setup used to study ultrasounds